SYSTEMS OF THE STARS[1]

By Robert G. Aitken

It has long been known that our Sun is a star differing in no essential quality from thousands of the stars visible in our night sky and of no greater importance, probably, than any other star in the general economy of the universe. If this is true it would seem to follow as a natural corollary that our solar system is typical of stellar systems; that the stars in general are each attended by a retinue of larger or smaller planets, asteroids, comets and meteoric bodies. As a matter of fact, however, we have not a particle of observational evidence that a system similar to our own exists elsewhere in space. The only objects beyond the confines of the solar system which we have been able to observe are self-luminous bodies, the stars and the nebulae[2].

I do not mean to imply that systems of the type of our solar system do not exist elsewhere. In all probability they do, and it can even be shown, as Newcomb and others have pointed out, that there is a "strong probability" that habitable and inhabited planets are numerous in such stellar systems. The argument, however, does not rest upon direct observation, but rather upon the mathematical theory of probabilities.

On the other hand we have abundant observational evidence of the existence of stellar systems of a strikingly different type; systems in which all of the known members are stars and hence of the same order of mass[3]. These are the binary stars and the star clusters.

These stellar systems and the binary stars more particularly are the subject of my lecture this evening and it is my purpose to tell you something of what we have found out about them and how we have found it out. But first we must answer the questions—what is a binary star? what is a star cluster? A binary star consists of two stars so near each other and so distant from all other stars that they revolve in closed orbits about a common center under

[1]A lecture delivered under the auspices of the Astronomical Society of the Pacific in Native Sons Hall, San Francisco, Tuesday, December 28, 1920.

[2]Certain of the nebulae, however, like the *Merope* nebula in the *Pleiades*, may be shining by reflected light. The evidence is not yet conclusive.

[3]In the solar system 99 6/7 per cent of the matter is contained in the Sun; 1/7 of one per cent is divided up to form the planets and their satellites, the asteroids, comets, meteors and the finely divided material revealed to us by the Zodiacal Light. The component stars in binary systems, so far as known, do not differ greatly from each other in mass. No star in a binary system has been found to have a mass as small as 1/10 that of the Sun, and stars twenty times as massive as the Sun are exceedingly rare. It is probable that these statements will hold good for the stars in general as well as for the members of binary systems.

the influence of their mutual attractions. The angular distances between the two components of the known binary stars range from a very small fraction of a second of arc to a fraction of a minute of arc. Hence the components cannot be seen separately without the aid of a telescope. Many pairs, indeed, are invisible as double stars even with the most powerful telescopes, but are made known to us by other means.

A star cluster we may define as any group of stars whose members are moving together thru space. Doubtless, the stars of a cluster will be influenced in their relative motions by the attractions of the other members of the group, but up to the present time we have not been able to detect any changes due to these influences.

As a matter of convenience we shall speak of visual binaries, of spectroscopic binaries and of eclipsing binaries, for these group names correspond to the different methods used in discovering the systems and in studying their structure and the motions of their components.

Historically, the visual binaries come first. We are indebted to Sir William Herschel for the proof of their existence, tho a number of them had been discovered many years before his time and had been called *double stars*, just as we call them today. Their discoverers, however, had overlooked their significance and had regarded each pair as due to a chance alignment in space of two unrelated stars. All of the stars are so distant that they appear to us as merely luminous points on the surface of the same great celestial sphere, and there is nothing, except the difference in apparent brightness[4], to give the slightest clue to their relative distances. Hence we cannot immediately distinguish between perspective pairs and those which, like *Castor*, form what Herschel styled "real double stars." In any particular instance it may be necessary to analyze a long series of careful measures of the relative positions of the two stars to decide the nature of the pair. That is the course Herschel followed. He compared his measures over an interval of about 20 years of the relative positions of the components in a number of systems and showed that in the case of the double star *Castor* as well as in some others, the

[4]*On the average*, the fainter stars are doubtless the more distant ones, but in any particular instance the apparent brightness of a star is a most unreliable guide to its distance. Eleven of the twenty stars listed as nearest to us in space are telescopic stars, while only four are as bright as the second magnitude.

two components were in relative motion of such nature that it could be explained only on the theory of a physical relationship between the two.

Measures of a double star are made with some form of micrometer attached to the telescope and give us the direction and the angular distance of one component from the other at the date of observation. That is, they tell us the relative positions of the two stars on the face of the sky, but they do not tell us anything, directly, of their relative distances from us. Yet it is possible from a series of such measures to discriminate between physical systems (Herschel's "real double stars,") and the purely optical or perspective association of two independent stars. For we have learned that the motions of stars thru space are of uniform velocity and either along straight lines or else in orbits of such vast dimensions that we cannot distinguish the arcs described in the few centuries covered by our measures from absolutely straight lines. Hence if a series of measures of a pair of stars shows that the relative motion is rectilinear and uniform, we may dismiss the pair at once as merely a perspective one. If, on the other hand, the relative motion tho apparently rectilinear is variable in its rate, or if the apparent path is a curve we confidently conclude that we are dealing with a physical system.

Even today our knowledge of stellar motions and of stellar systems is very incomplete; in Herschel's time it was fragmentary indeed; hence it is not at all surprising that astronomers in general then thought that physical pairs would prove to be the exception and perspective pairs the rule. We must remember that only a few hundred double stars, nearly all of them of Herschel's own discovery, were then known. The labors of later astronomers, particularly within the last half century, have so vastly increased the number, that we cannot escape the conclusion that, in general, the double stars are physical systems. Indeed, it can be, and repeatedly has been shown that very few accidental or perspective pairs are to be expected among the double stars whose components are separated by only a few seconds of arc. Of the 10,000 closest known pairs, probably 99 per cent are physical systems. Hence while in particular instances we may still have to rely upon long series of careful measures to decide the nature of the pair, we may in general safely proceed upon the assumption that a close double star is a binary system until the contrary has been proved. Binary

star systems are evidently one of the standard products of the forces of stellar evolution.

The law governing the motions of the components in binary star systems was the subject of first interest after Herschel's epoch-making discovery. That it would prove to be identical with the law of gravitation was assumed at once, and the evidence in favor of this assumption long ago became so strong as to amount to conclusive proof. The first great generalization, therefore, to which the study of double stars has led is that the law of gravitation is of universal validity[5]. On this we confidently base all of our studies of stellar motions. We find that the orbits of binary stars computed on the basis of this law permit us not only to represent existing observations within the limits of unavoidable error of measure but to predict the future motions of the components within the same limits.

No measure is absolutely accurate, for the human hand and eye and brain are fallible, and the best of telescopes and measuring instruments have their limitations, but the double star observer labors under the additional handicap that his measures must in the nature of the case be made in angular units. To convert them into linear units (miles or kilometers) a knowledge of the distance of the objects is required. Under the best conditions he can measure the angular distance of one star from another with an error not greater than $0''.01$. This is an extremely small quantity. It corresponds to a linear displacement of only one foot if the objects measured are 3900 miles distant, and at the distance of the Sun, 93,000,000 miles, it amounts to less than 5 miles. But the nearest star is 275,000 times as distant as the Sun is from the Earth and the majority of visual binaries which we measure are from 10 to 100 times more distant still. The extremely small angular error of $0''.01$ in our measures of a double star therefore corresponds to a linear error of millions of miles in the relative positions of the components. Hence we cannot hope to detect in binary star systems such slight departures from simple elliptic motion as those produced in our planetary orbits by the "perturbing" attractions of the other planets.

We do indeed occasionally find periodic irregularities in the apparent motion of the companion star with respect to its primary

[5]A rigorous mathematical demonstration of the universality of the law of gravitation is possible only if we assume that the attraction between two bodies is independent of their orientation, but there is no reason to question the correctness of this assumption.

which cannot be explained on any hypothesis other than the presence of a third body in the system, but this body must be of stellar, not of planetary mass. Take *Epsilon Hydrae*, for example, which Struve in 1825 found to be a double star with an angular distance of $3''.3$ between the components. The measures show a grouping in the companion's position at 15 year intervals which causes the apparent path to resemble a series of loops along an elliptic curve. In 1888 Schiaparelli discovered the primary star to be itself a very close double with a distance of only $0''.25$ between the two unequally bright components. It has since developed that this close pair is revolving in a relatively small orbit with a period of about 15.3 years. When the observed positions of the more distant Struve companion are corrected so that they are referred to the center of mass of the close pair and not to the center of light, the periodic irregularities in its motion disappear. In the system of *Zeta Cancri*, and in one or two other systems, where we find similar irregularities, the disturbing star has not yet been discovered. It is doubtless so faint that it is lost in the light of the bright star which it attends.

Our measures of a binary star, made in angular units, enable us to make a correct plot of its apparent orbit, and from this we can derive the elements of its true orbit in space. If our measures are accurate enough we shall know the form and the orientation of this orbit, the positions of the stars in the orbit at any given time and the length of time required for one complete revolution. But we cannot determine the linear dimensions of the orbit until we know the parallax (distance from us) of the system. We are in the position of a man who has the map of a country, or the plan of a building drawn accurately to scale, but who does not know the scale. Fortunately, our colleagues who are engaged in parallax work have given us quite precise values for the distances of a number of binary stars for which we also have good orbits. In these cases we are able to determine not only the dimensions of the system but also its mass in terms of the Sun's mass, for the periods, mean distances between components and the masses of two systems stand in a definite relationship which is expressed by Kepler's Harmonic Law. Further, if we have an adequate series of measures connecting one star of a binary system with an independent star or can in any other way determine its motion with respect to the center of gravity of the system, we can also derive the relative masses of the two components.

From such data we find that the orbits of the visual binaries with periods under 200 years correspond very fairly in size with the orbits of the outer planets of the solar system; very few are smaller than the orbit of *Jupiter*, several are as large as the orbit of *Neptune*. What the upper limit in the size of longer period binaries may be we cannot as yet say, but it is certain that it will be much larger than the orbit of *Neptune*. The form of the binary star orbits, however, is strikingly different from that of our planetary orbits. The latter, with the exception of that of *Mercury*, are nearly circular, the former as a rule markedly elliptical, the average eccentricity being about 0.5. Further, it appears that, on the average, the orbits with the longer periods are those with the higher eccentricities. We also find that the average visual binary star has a mass approximately twice that of the Sun and that the range in mass is small. Data of this kind are of great significance in our studies of stellar conditions and we shall refer to them again a little later.

A knowledge of the number and of the distribution of the visual binary stars is also a matter of great interest. It was for the purpose of securing definite information on these points that I initiated, early in 1899, the survey of the stars in the northern sky which Professor Hussey and I carried on in collaboration until he left the Lick Observatory in 1905 and which I completed in 1915. We examined every star as bright as 9.0 magnitude, and many of 9.1 magnitude, from the north pole to 14° south declination in the winter sky and to 22° south declination in the summer sky, checking the identification of every known double star and cataloging and measuring more than 4300 additional close pairs.

From a statistical discussion of the data I found that at least one star in every 18, on the average, of those as bright as 9.0 magnitude in the northern half of the sky was a close double star within the resolving power of the 36-inch refractor. It also appeared that the percentage of double stars was greater in the regions of the Milky Way, and that the percentage was somewhat greater among the brighter than among the fainter stars, and among stars of the spectral classes F and G than among those of either earlier or later spectral class[6].

[6]The magnitudes referred to in this paragraph are those given in the *Durchmusterungen* of Argelander and Schönfeld, and differ slightly from those on the Harvard photometric scale. It should also be noted that the statistical results relate simply to the apparent data. The seeming preference of visual double stars for the spectral classes F and G, for example, may be due to the fact that stars of these classes, on the average, are nearer to us than those of classes B. A, K or M. M. Jonckheere, from an independent discussion based on somewhat different data. finds that the percentage of double stars is highest in regions of greatest star density.

It is obvious that no survey, however inclusive and careful and however powerful the telescope with which it is made, will give us a complete knowledge of the number of binary stars. At present, the limit of resolving power of our greatest telescopes is of the order of 0″.10; and even tho the recent development of the interferometer at the Mount Wilson Observatory reduces the limit to less than 0″.05, at least for the brighter stars, many systems must still escape detection. A double star system, for example, of such vast dimensions that centuries are required for a single revolution of its component stars may still be so distant from us that the angular separation between these components is less than 0″.01. At present we have no means of distinguishing such systems from single stars. On the other hand, the angular separation of two stars of a system may be equally small because the two are actually very close together. But in the latter case, while we can never see the stars separately in any telescope, we may still know that they exist; and not only that, we may even investigate their orbital motions and this with a higher degree of accuracy than is possible in the case of the most favorably placed visual binary star.

The instrument with which we accomplish this is the spectrograph, whose properties and possibilities have been discussed in the preceding lectures of this course by Professors Lewis and Moore. The orbital motion in these very close pairs must be very rapid and the revolution period correspondingly short. Unless the plane of the system is almost perpendicular to the line of sight this rapid orbital motion must produce large variations in the radial velocities of the stars, and these variations will be reflected by the displacements of the lines in the star's spectrum from their mean positions alternately toward the red and toward the violet end. A good series of spectrograms thus provides the data for a determination of the orbit elements of the system[7].

Spectrographic measures of radial velocity are made directly in linear units—miles or kilometers per second. They thus have the great advantage of being independent of the distance of the star. If we can secure a good spectrogram of a star 10,000 light years

[7]From spectrographic observations alone we can determine neither the position of the line of nodes nor the inclination of the orbit plane, but we know the times when the star passes its nodal points and can distinguish between the two nodes. We can also find the value of the function $a \sin i$, the product of the semi-major axis by the sine of the angle of inclination, but not the value of a or i separately. Visual observations, on the other hand, give the values of a and of the position of the line of nodes but cannot distinguish between the two nodal points and therefore leave an uncertainty of 90° in the inclination. When we can compute the orbit of the same pair from both spectrographic and micrometric measures, as in the case of *Epsilon Hydrae*, a complete knowledge of the orbit elements and dimensions results.

distant, we can measure its radial velocity as accurately as that of *Alpha Centauri* only 4½ light years away. Add the fact that, in general, the revolution periods of the known spectroscopic binaries are very short, ranging from a fraction of a day to a few months or years, whereas the periods of the known visual binaries range from a minimum of 5½ years (*Delta Equulei*) to a maximum of an unknown number of centuries, and it will not seem strange that we already have more orbits, and more accurate orbits, of spectroscopic than of visual binaries, tho the first spectroscopic binary was discovered (by E. C. Pickering) as recently as 1889.

Powerful as it is, the spectrograph, too, has its limitations as an instrument for discovering binary star systems and studying their motions. If the revolution period is long or the orbit plane nearly perpendicular to the line of sight, the variation in the radial velocity may be so small that it will be masked by the unavoidable errors of measure, particularly in the case of stars whose spectral lines are broad and hazy. In other cases, altho the period is very short and the lines sharply defined, the star may be so faint photographically that the exposure time required to record a measurable spectrogram may equal or even exceed the entire revolution period. Our knowledge, however, of the radial velocities of the stars as bright as 5.0 photographic magnitude is now sufficiently complete to show that at least two-fifths of them are spectroscopic binaries. Since there is no good reason for thinking that the fainter stars, with the possible exception of those in the great clusters and in the distant star clouds of the Milky Way, are essentially different from the brighter ones, it is probably safe to say that nearly one half of the stars are binary systems.

In particular cases we have a third method of discovering binary stars and of investigating their motions. Suppose that the orbit plane of a short period binary star is so nearly parallel to the line of sight that each star is eclipsed by the other once in every revolution. We then have a variable star whose light curve has distinctive features which are easily recognized. More than 150 such eclipsing binaries are now known. Sometimes, as in *Beta Lyrae,* the two stars are of nearly equal brightness, sometimes, as in *Algol,* one star is so much fainter than the other that its eclipse scarcely affects the total light received by us from the system. The development of extremely sensitive photometers in recent years has made it possible to measure very slight variations in the

light intensities of the stars and it has been found practicable to utilize these measures in studies of the orbital motions in the eclipsing binary systems. The most recent and most extensive investigation of this kind is the one carried out by Russell and Shapley at Princeton University, the former being chiefly responsible for the development of the theory, the latter, for its application to 90 different systems.

We have, then, three independent methods of investigating the motions in binary star systems—four, indeed, if we include the interferometer, which has already been successfully applied to a discussion of the orbit of *Capella*. Each has its own advantages, but, unfortunately, we cannot apply them all to the study of the same system. No visual binary is now known that is also an eclipsing variable star, and it is only rarely possible to measure the variation in the radial velocities of the components of a visual binary except when they are near the point of periastron passage. Every eclipsing variable, however, that is bright enough to be studied to advantage with the spectrograph has been shown to be a spectroscopic binary.

The comparative study of the numerous binary star orbits now available has revealed a strong correlation between the length of the revolution period and the eccentricity of the orbit. In general, when the periods are short, the orbits are nearly circular; when the periods are long, the orbits are of high eccentricity. This relation holds for stars of all spectral classes, and for the "giants" as well as for the "dwarfs" tho, as I pointed out several years ago, the curve showing this relationship is not of uniform slope, but has what we may call a "hump" in it[8].

I have already said that the mass of the average visual binary system is approximately twice that of the Sun and that the range in mass is small. A similar statement applies to the spectroscopic binary systems, but there is an apparent relationship between the mass and the spectral class, systems of spectral class B being the most massive, those of class M least massive. With very few exceptions the brighter star of a system is the more massive one, but the disparity in mass is never very great. One star of a pair may

[8]A recent investigation by Dr. Ralph Wilson shows that when separate period-eccentricity relationship curves are drawn for the giants and for the dwarfs, the former lies always above the latter (the eccentricities being taken as the ordinates). It also appears that the "hump" in the combined curve is due chiefly to the giant stars. Dr. Wilson thinks the explanation for the hump is to be found largely in the difficulty of detecting spectroscopic binaries of long period and high eccentricity.

be two or three or four times as massive as the other but not fifty times. In many, possibly in the majority of cases, the components are of nearly equal mass. Utilizing this generalization as to relative mass of the components we can derive the densities of the stars in eclipsing binary systems. On the basis of what appear to be legitimate assumptions we can also compute the densities of the visual binaries. In this particular, we find an enormous range; some stars are apparently less than one ten-thousandth part as dense as the Sun, others exceed the Sun in density.

All of these generalizations have a bearing upon the question of the origin of the binary stars and also upon the more general problem of stellar evolution. Unfortunately, the data are still very meager, and we must remember further that the systems for which we now have orbits may not be representative even of the binary stars as a whole, to say nothing of the single stars, for they are of necessity selected stars—those most easily detected as visual or spectroscopic binaries by reason of favorable location and orientation in space. Consequently it is impossible as yet to frame any completely satisfactory theory of the origin of binary systems. It has been suggested that they may have developed from primal single stars by a process of "fission," the two components revolving at first in surface contact in circular orbits, and being gradually driven farther apart and into orbits of greater ellipticity by the action of tidal forces. For the very close spectroscopic binaries this theory has much observational evidence in its favor, but if the wider visual pairs developed in this way we must look for some force or forces in addition to that of tidal friction to account for the present dimensions and forms of their orbits.

Again it has been suggested that binaries may have originated in what we may term the entangling encounter of two independent stars. The long period, highly eccentric orbits would, on this theory, belong to systems of comparatively recent origin, and the short period, nearly circular orbits to the very old systems. But the chances for such encounters in the present state of the stellar universe are extremely small, and the number of binaries is extremely great. To make this theory at all plausible we must assume an antecedent state of the universe in which the stars were crowded into a much smaller space.

Finally, we may assume that the primal nebular matter out of which each system developed began to condense about two separate

nuclei, which, as condensation progressed, began to revolve about each other under the force of their mutual attraction. By varying the conditions suitably it is obvious that we can thus account for almost every possible variety of system, and for this reason alone, if for no other, the theory really explains nothing at all. We must accumulate more data and gain further knowledge of the forces at play in the universe before we can solve problems of this kind.

Much still remains to be said about the binary stars and other stellar systems, but the limits of this paper will permit only a brief account of certain multiple stars, and a mere reference to the more complex systems which we call star clusters.

I have already called attention to the triple systems *Epsilon Hydrae* and *Zeta Cancri*. A number of such systems are known, and, as Russell has pointed out, they consist always of a relatively close pair and a third star at a much greater distance. The close pair is often a spectroscopic binary. Instead of three stars we not infrequently have four, grouped as two pairs separated by a distance which is great relatively to the distance between the components of either pair. All four stars may be visible, or one or even both close pairs may be spectroscopic binary stars. Thus *Castor* was one of the first visual binary stars to be discovered, and its orbit is of such dimensions that the period of revolution is at least 350 years. But each of the bright stars of the pair is a spectroscopic binary, the period being 9 days in the one case and less than 3 days in the other. In such systems as these all of the stars are in orbital motion. But we often find more widely separated stars which are moving together thru space but whose exact relationship is not so clear. Thus there is a very distant companion moving thru space with *Capella*, another one with *Alpha Centauri*, and *Castor* itself has a travelling companion 73″ distant of 9.5 magnitude which is also a spectroscopic binary star. More remarkable still, perhaps, are some of the faint pairs which have recently been discovered by Max Wolf at Heidelberg and Innes at Johannesberg by photographic methods. One of the most striking of these is a quadruple announced by Max Wolf. Two wide pairs of stars with distances between their components respectively 3′ and 6½′ are separated from each other by fully 4°, and yet all four stars are apparently moving thru space in precisely the same direction and at the same rate.

In such wide pairs we are not dealing with cases of orbital motion in the usual sense, for if the stars are revolving about common centers the revolution periods must be measured in tens or hundreds of thousands of years. Perhaps we have in these groups what we may term a connecting link between binary star systems and those of the cluster type. I do not mean to imply that there is any genetic relationship between the two classes, but simply that since the constituent stars of every system of either class have a common motion thru space and this property is shared also by these wide pairs, we may for the present regard them either as binaries of abnormally great dimensions or as star clusters of only three or four members. For common motion thru space is generally accepted as sufficient evidence of the physical relationship of stars, whether there are only two, as in a binary, or many as in a cluster.

The clusters themselves are of several varieties. Some are "open" or irregular, like the *Pleiades*, or the double cluster in *Perseus*; others consist of stars distributed over so great an area of the sky that they have no cluster-like appearance at all and are recognized only by the common motion thru space of their members. Such are the "moving clusters" in *Taurus* and in *Ursa Major*. In still other cases we find many hundreds or even many thousands of stars collected into groups called, from their form, globular clusters. The finest one in the northern sky is the great cluster in *Hercules*. As I have already said, we have, so far, no evidence in any of these systems of internal motions due to the mutual attractions of the stars composing them. Nevertheless investigations of these objects by modern photographic and spectrographic methods are giving us some insight into their structure and these results are in many ways affecting our general theories of the stellar universe[9].

But, after all, the binary and multiple stars and the star clusters, even the greatest of them, are simply local star systems. So too are the many systems resembling in greater or less degree our solar system which doubtless exist. The question arises, are they all members of a greater system? I believe that they are. The more we learn about stellar motions and the laws that govern them the more convincing become the evidences of an all-comprehensive organic structure. Possibly this may be vast enough to include

[9]When the lecture was delivered slides of many clusters were exhibited and some details of these modern investigations were presented.

every object revealed to us by our telescopes; or it may be that the single and multiple stars and the star-clusters of our galaxy, together with the irregular and the planetary nebulae form but an "island universe," and that in the spiral nebulae we have the visible evidence of the existence of hundreds of thousands of other galaxies perhaps as large and rich and diversified as our own and all of them units in a system of a still higher order.

PLANETARY PHENOMENA FOR NOVEMBER AND DECEMBER, 1921

By Malcolm McNeill

PHASES OF THE MOON, PACIFIC TIME

First Quarter....Nov.	7, 7^h54^m A.M.		First Quarter...Dec.	7, 5^h20^m A.M.	
Full Moon....... "	15, 5 39 A.M.		Full Moon...... "	14, 6 51 P.M.	
Last Quarter..... "	22, 3 41 A.M.		Last Quarter.... "	21, 11 54 A.M.	
New Moon...... "	29, 5 26 A.M.		New Moon..... "	28, 9 39 P.M.	

The Sun reaches the winter solstice, its farthest southern position, and begins its northern journey on December 22, 1^h8^m A. M., Pacific Time.

Mercury passed inferior conjunction with the Sun on October 31, becoming a morning star. It remains a morning star until it reaches superior conjunction on December 27. It reaches greatest west elongation, $19°27'$, on November 16, rising on that date somewhat more than an hour and a half before sunrise. The interval will be more than an hour from a few days before November 16 until after December 1, and the planet can be seen in the early morning twilight under good weather conditions thru-out this period. The elongation is rather small as it occurs only ten days after the planet passes its perihelion, and the duration of naked eye visibility is somewhat less than is usual for greatest west elongations occurring at this season.

Venus remains a morning star rising about two hours before sunrise on November 1, but this interval shortens up to only a little more than half an hour by December 31. The planet's motion among the stars is quite rapid, 75° eastward and 19° southward among the stars, from *Virgo* thru *Libra* and *Scorpio* into *Sagittarius*. On November 6 it passes about 4° north of *Spica, α Virginis*, and on December 13 about 6° north of *Antares, α Scorpii*. Altho *Venus* is now on the far side of its orbit from the Earth and draw-